Amitava Rakshit
S. K. Singh
P. C. Abhilash
Asim Biswas *Editors*

Soil Science: Fundamentals to Recent Advances

Springer

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To our parents for their unbiased support

Preface

Human society has developed through utilization of our planet's wealth in incredibly exclusive, inventive, and prolific ways that have advanced human advancement and sustained global societies. Of these resources, soil is the most important economic industry that has provided humans with the ability to produce food, through agriculture, for our sustenance. It also plays an integral role in countless other ecosystem services like water and climate regulation. In exploring the link between soil and agriculture, we have moved through phases like transition from hunter-gatherer to agrarian societies, major soil properties that contribute to fertility, intensive agriculture impact on soil degradation, and the basic concepts of sustainable agriculture and soil management. All through human history, our association with the soil has affected our aptitude to cultivate crops and influenced the accomplishment of civilizations. This rapport between humans, the earth, and food sources affirms soil as the foundation of agriculture. Soils are important for human health in a number of ways. Approximately 80% of the average per capita calorie consumption worldwide comes from crops grown directly in soil, and another nearly 20% comes from terrestrial food sources that rely indirectly on soil. Soils are also a major source of nutrients, and they act as natural filters to remove contaminants from water. However, soils may contain heavy metals, chemicals, or pathogens that have the potential to negatively impact human health. In the present context, soil science has to play a more serious role to its stakeholders in times to come. It is high time to get rid of over-generalizing recommendations beyond the conditions for which they were developed. There is an urgent need to communicate the risks inherent in the recommendations and finally findings need to be translated into economic terms so that farmers and policy-makers can work with them.

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S. K. Singh received his B.Sc.(Ag) degree in 1985 and M.Sc.(Ag) in 1988 and Ph.D. in Soil Science and Agricultural Chemistry in 1992 from Banaras Hindu University, Varanasi. He started his professional career in 1990 as Lecturer of Agricultural Chemistry in Amar Singh (PG) College, Lakhaoti, Bulandshahr subsequently Dr Singh joined as Associate Professor in the year 1999 at G.B. Pant University of Agriculture and

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Asim Biswas is an Associate Professor at the School of Environmental Science, University of Guelph, Canada. He is also an Adjunct Professor at the Department of Natural Resources Sciences, McGill University Canada, a Visiting Professor at Jiangxi University of Finance and Economics and Jiangsu University, China. His research program on sustainable soil management is focused on increasing the productivity and resilience of our landbased agri-food production systems in an environmentally sustainable way while accounting for changing climate, economy, and production methodologies. Currently, he runs a 21-member research team, funded by federal and provincial bodies as well as industries, grower's associations, and international organizations. He has authored and co-authored 113 peer-reviewed journal papers including 21 in review, 165 conference abstracts, 12 proceedings, 15 book chapters, 2 popular articles, edited a book, delivered radio and TV interviews, and granted a patent. He was invited to deliver keynote talks around the world and currently teaches multiple undergraduate, graduate, and special courses. Currently, he is an Associate Editor for 4 journals and a guest editor for another 4 journals.

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Part I

General Concepts and Development

Managing Soil Resources for Human Health and Environmental Sustainability

1

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Abstract

Rapidly increasing global human population has led to the intensive land use change, and the over exploitation of soil resources resulting in the diminished soil health, ecosystem services, and human well-being. Depriving nutrients from the soil systems due unsustainable practices has further led to low productivity and quality of the crop yields. As a result, it led to the scarcity of the food with limiting nutrients reflecting various nutrient deficiencies and human health disorders. Therefore, it is the need of the hour to restore the health of our soil resources for improving the food and nutrition secuirty of present as well as future generations. In this backdrop, the present chapter is aimed to discuss the drivers of soil degradation, highlight the impact of soil degradation on human health and suggests various adaptive practices to maintain the soil health while improving the quality of crop yield for environmental sustainability and human health.

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Keywords

Soil degradation · Soil health · Adaptive management · Sustainable development · Human health

1.1 Introduction

Soil is one of the important life-supporting resources of the planet earth. It not only provides food, fodder, fuel, and fiber but also regulates the quality of air and water (Rakshit et al. 2017; Tripathi et al. 2017). However, the increasing anthropogenic activities coupled with unsustainable soil management practices lead to desertification, pollution, reduced biodiversity, and organic matter content (Tripathi et al. 2014). The low nutrient status in soil has resulted in decreased productivity and nutrients in crops, thereby negatively affecting the good health and human well-being (IPBES 2018). It has been estimated that around 33% of the global soil resources are in a state of degradation, affecting the livelihoods of billions (Wall and Six 2015; IPBES 2018). As the rapidly increasing human population require 50–70% increase in the production of food, fiber, and fodder in the near future, the arable land requirement for meeting such demand is about 2.7–4.9 M ha y^{-1} (Lambin and Meyfroidt 2011; Abhilash et al. 2016). While soil fertility is replenishable up to a certain extent, it will take hundreds of years to regain the vitality of the soil to maintain the critical soil ecosystem functions and services. In this backdrop, the sustainable management of the global soil resources is imperative to meet the food and nutritional security of the growing population while maintaining the soil fertility, productivity and soil ecosystem services for meeting the UN-Sustainable Development Goals (Dubey et al. 2016; Edrisi and Abhilash 2016; Sarkar et al. 2020). Considering the importance of soil resources for sustainable agriculture and human health and thereby creating a global solidary for the conservation and management of soil, United Nations has declared the period of 2015–2024 as International Decade of Soil, whereas the decade 2021–2030 as the International Decade of Ecosystem Restoration. Moreover, a lot of international efforts are underway to increase the awareness about the sustainable management of global soil resources (Lambin and Meyfroidt 2011; Edrisi et al. 2019) and restoring the already degraded soil to regain the fertility and ecosystem functions for a good quality of human life (IRP 2019). The present article briefly discusses various drivers of soil degradation, the impact of soil quality degradation on crop production as well as human health and propose suitable management practices for maintaining the vitality of soil.

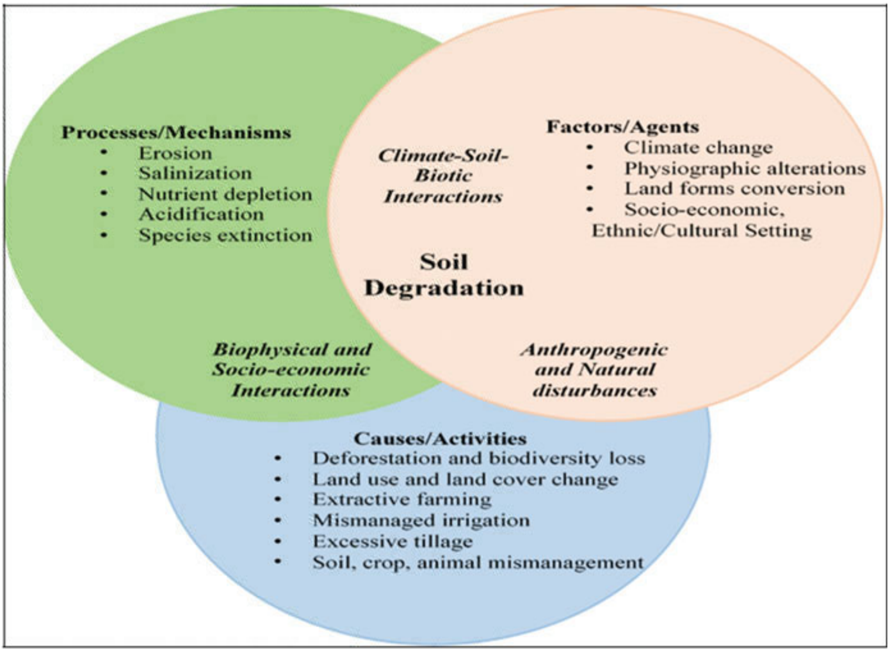

Fig. 1.1 The nexus of different processes, factors, and causes as major indicators of soil degradation (adapted from Lal 2015; IPBES 2018)

1.2 Drivers of Soil Degradation

As mentioned in Fig. 1.1, there are several interconnected factors affecting the degradation of the soil resources such as (1) climate–soil–biotic interactions, (2) biophysical and socio-economic interactions, and (3) the anthropogenic and natural disturbances (Fig. 1.1). Periodic monitoring of these interactions is required to understand the behavior of various drivers on soil ecosystem functions and services and also for the implementation of efficient restoration and management approaches (Tripathi et al. 2014; Edrisi et al. 2019).

1.3 Soil Degradation and Human Health

Quality of soil is directly related to malnutrition and basic public health issues (McMichael et al. 2007). Accordingly, the degradation of soil quality directly and indirectly affects the human nutrition and health because of the fact that soil quality degradation decreases both the quantity and quality of the agricultural produce (IRP 2019).

Therefore, reduced crop yield has resulted in global food scarcity which in turn affects over 854 million peoples across the world. Moreover, the reduced concentration of proteins and micronutrients (Zn, Se, Fe, I, etc.) leads to malnutrition and hidden hunger affecting 3.7 billion population, particularly the children (Lal 2009). In addition to the insufficient calorie intake, micronutrient deficiencies are the common reason for mortality (Black 2003; Ezzati et al. 2002), and especially, children are more susceptible to Zn (Sazawal et al. 2001) and vitamin A (Humphrey et al. 1992) deficiencies. For instance, half of the mortality rate of children under the age of five in India are mainly due to under nutrition (data.unicef.org).

Similarly, around 24% of all children in China are victims of Fe deficiency, while over 50% suffer from of Zn deficiency (Yang et al. 2007). Keshan and Kaschin–Beck diseases occur in regions of soils with lower Se concentration (Yang et al. 2007). With rapid industrialization, soil contamination (e.g., Pb and As pollution) represents severe health concern in China and developing countries like India (Chen 2007; Qi et al. 2007). Brick kilns, in rapidly urbanizing India, consumes annually 1 m of topsoil from 0.5% to 0.7% of cropland area particularly in the northern states of Haryana and Punjab. Food crops grown on shallow soils are deficient in micronutrients. Pimentel et al. (2007) attributed occurrence of several human diseases to air, water, and soil pollution. Following the massive deforestation, hookworm infection has been increased by 12% of the population in Haiti in the year 1990, which further enhanced up to 15% in 1996 (Lilley 1997). Dry land salinity already affecting 1.05 million hectare (Mha) in southwest Australia, and have potential risk of disseminating to 1.7 or even up to 3.4 Mha and has intense human health implications (Jardine et al. 2007).

Hence, there is a close proximity between the mismanaged practices adopted and the depleting soil and human health (Fig. 1.2). This could be either in the form of land use or the overexploitation of such soil resources resulting in the soil erosion and other loss of soil nutrient status, which subsequently leads to the degradation of these natural resources. This rises the scenario of food and nutrient scarcity for the associated peoples, involved labors, and other stakeholders might lead to their retarded or serious health impacts and thereby diminishing their work efficiency (Fig. 1.2).

1.4 Strategies for the Management of Soil Resources

Adaptive management practices can play vital role in combating nutrient depletion managing problem soils, managing soil erosion, and optimizing soil-water use. Adaptive management can be generally defined as an iterative decision-making tool which is both operationally and conceptually a simple aid that incorporates users to acknowledge and account for uncertainty and sustain an operating environment that allows for its reduction through careful planning, evaluation learning until desired results are achieved (Rakshit et al. 2017). It has been reported that various edible crops have also been grown from the polluted lands to serve the burgeoning global population (Ilbas et al. 2012; Meers et al. 2010; Yu et al. 2014; Warren et al.

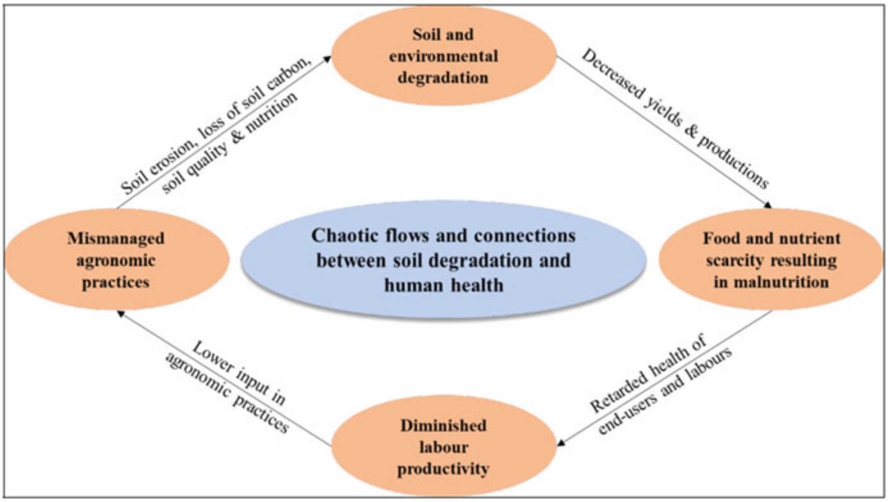

Fig. 1.2 Schematic depiction of soil degradation and human health (modified from Deckelbaum et al. 2006)

2003; Stasinos and Zabetakis 2013). Ilbas et al. (2012) have grown barley in the selenium contaminated field and estimated the Se level to be 0.17 mg kg^{-1}.

Moreover, Meers et al. (2010) have studied the growth of Maize crops in the multi-contaminant polluted land and restricted the Cd, Pb, Zn level in the grains to 0.07 mg kg^{-1}, 0.10 mg kg^{-1}, 0.73 mg kg^{-1}, respectively, which are under the permissible limit as per the FAO standards. Yu et al. (2014) studied the performance of Rice and Rapeseed in the mixed-contaminated sites and observed the levels of Zn (22.8–23.8 mg kg^{-1}) and Cd (0.1 mg kg^{-1}) in the rice and the Cd (0.2 mg kg^{-1}) in the rapeseed, which are under the permissible limit as per the WHO standards. Warren et al. (2003) have also restricted the level of As (<0.08 mg kg^{-1}) in the edible parts of Beetroot grown in the As-contaminated soils in the field. Similarly, Stasinos and Zabetakis (2013) have observed the level of Ni in the carrot, which is estimated to be 0.73 mg kg^{-1} in the Ni contaminated sites. All the aforesaid researches have made use of either the plant growth promoting rhizobacteria (PGPR), arbuscular mycorrhizal fungus (AMF), or other novel plant growth promoting microorganisms (PGPMs) in the consortia which have provided the potentials to those plant species to tolerate such adverse conditions in field. Also the endophytic microorganisms had played a vital role in restricting the pollutant levels to the permissible limit for human intake as dietary supplements.

There are various regional and international initiatives for soil resource management that focused on enhancing the resource use efficiency such as correcting micro and secondary nutrient deficiencies in the soil has shown to increase crop productivity by 20–66% in Karnataka, India (Wani et al. 2017). As a result, five million farmers have been benefitted and has the net economic benefits through enhanced production were estimated to be around US$353 million (1963 crores). Furthermore, the importance of traditional ecological knowledge (TEK) has also been viewed as a pertinent practical solution to the soil restoration and its management (Sharma 2017). Agro-ecosystem management practices, which are the proximate part of the TEK are attracting attention due to its better adaptability and sustainability. Bio-mulching, seed treatments, native seeds and varieties, bioformulations, vermicompost, natural pesticides, livestock rearing are some of the TEKs which has been utilized in different regions of India to uplift the sustainable productions. Semi-arid tropical zone like the region of Kachchh in Gujarat has been employed with these TEKs and found to have better health of soil regarding the phosphorus availability in the soil via phosphate solubilizing microbes (Sharma et al. 2014).

Moreover, the impacts of natural perturbations like forest fire and other changes on soil properties and human environments should also be focused to maintain the viability of such ecosystems (Zhang and Biswas 2017). Adaptive management could play a vital in managing these issues for maintaining the soil carbon pool in the boreal forests. Norris et al. (2009) compared the response of SOC content at 4, 29, and 91 years following disturbance and reported a drastic carbon loss at 4 years after the fire, while gradually rising again over a long period (SOC from 2% after 4 years to 33% after 91 years for forest floors). Apart from the SOC, various other nutrients such as nitrogen, phosphorus, and many base cations like potassium, calcium, etc. are also lost in the forest fire regimes, depleting the soil quality, rising GHG emissions and hence the adverse impact on the human health. To overcome such scenarios, predicting the future forest fires via geospatial technology could play an empirical role (Bui et al. 2019). Also, there is an urgency to monitor the quality of soil health in other ecosystems like urban and riparian systems to devise suitable management actions accordingly.

Since, there is a potential disagreement between the social and ecological goals for the ecosystem restoration (Dudley et al. 2005), hence most of the restoration projects which either ranked the social or economic needs that failed to effectively address broader ecological impacts or focused on narrow mitigation targets without considering the fundamental needs of the people (IRP 2019). It is evident from the past that the indigenous peoples and traditional farmers often developed diverse and adapted agroforestry systems in the vicinity. This resulted in local food security, conserving regional biodiversity and ensued socio-ecological resilience (Altieri 2004; Parrotta et al. 2015; IRP 2019). Such systems can be recognized by studying the possible trade-offs between the benefits of diverse agro-ecosystems and changes in the staple crops production. In order to address these challenges, accounting landscape variability while planning rehabilitation and restoration allows many of the trade-offs for alleviating hunger, while increasing the potential co-benefits (IRP 2019). Such trade-offs can be avoided by providing temporary access to land in another part of the landscape or by intensifying production on one part of the farmer's land while taking another part out of production. Co-benefits can be enhanced by targeting such restoration funds where the most returns are possible.

1.5 Conclusion and Way Forward

Widespread multi-nutrient deficiencies and deteriorating soil health are the causes of low nutrient-use efficiency, productivity, and profitability. Apart from this, the related issues of the climate change have created the enhanced depletion of soil quality, availability of irrigation water and use efficiency of resources and inputs, and crop productivity. The adoption of climate resilient practices along with the application of remote sensing, GIS and advanced restoration technologies are imperative for restoring the fertility of the soil health for sustainable development. This would not only help in combating climate change issues but also help in formulating strong policies for managing soil resources.

References

Abhilash PC, Tripathi V, Edrisi SA, Dubey RK, Bakshi M, Dubey PK, Singh HB, Ebbs SD (2016) Sustainability of crop production from polluted lands. Energ Ecol Environ 1:54–65

Altieri MA (2004) Linking ecologists and tradition in the search for sustainable agriculture. Ecol Soc Am 2:35–42

Black R (2003) Micronutrient deficiency—an underlying cause of morbidity and mortality. Bull WHO 81:79

Bui DT, Hoang ND, Samui P (2019) Spatial pattern analysis and prediction of forest fire using new machine learning approach of multivariate adaptive regression splines and differential flower pollination optimization: a case study at Lao Cai province (Viet Nam). J Environ Manag 237:476–487

Chen J (2007) Rapid urbanization in China: a real challenge to soil protection and food security. Catena 69:1–5

Deckelbaum RJ, Pam C, Mutuo P, DeClerck F (2006) Econutrition: implementation models from the Millennium Villages Project in Africa. Food Nutr Bull 27(4):335–342

Dubey RK, Tripathi V, Dubey PK, Singh HB, Abhilash PC (2016) Exploring rhizospheric interactions for agricultural sustainability: the need of integrative research on multi-trophic interactions. J Clean Prod 115:362–365

Dudley N, Mansourian S, Vallauri D (2005) Forest landscape restoration in context. In: Dud-ley N, Mansourian S, Vallauri D (eds) Forest restoration in landscapes: beyond planting trees. Springer, New York

Edrisi SA, Abhilash PC (2016) Exploring marginal and degraded lands for biomass and bioenergy production: an Indian scenario. Renew Sust Energ Rev 54:1537–1551

Edrisi SA, Tripathi V, Abhilash PC (2019) Performance Analysis and Soil Quality Indexing for *Dalbergia sissoo* Roxb. grown in marginal and degraded land of eastern Uttar Pradesh, India. Land 8:63

Ezzati M, Lopez AD, Rodgers A, Vanderhoorn S, Hurray CL (2002) Comparative risk assessment collaborating group. Selected major risk factors and global regional burden of disease. Lancet 360:1347–1360

Humphrey JH, West KP, Sommer A (1992) Vitamin A deficiency and attributable mortality among under-5 years-olds. Bull WHO 70:225–232

Ilbas AI, Yilmaz S, Akbulut M, Bogdevich O (2012) Uptake and distribution of selenium, nitrogen and sulfur in three barley cultivars subjected to selenium applications. J Plant Nutr 35:442–452

IPBES (2018) Montanarella L, Scholes R, Brainich A (eds) The IPBES assessment report on land degradation and restoration. Secretariat of theIntergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn. p 744

IRP (2019) Herrick JE, Abrahamse T, Abhilash PC, Ali SH, Alvarez-Torres P, Barau AS, Branquinho C, Chhatre A, Chotte JL, Cowie AL, Davis KF, Edrisi SA, Fennessy MS, Fletcher S, Flores-Díaz AC, Franco IB, Ganguli AC, Speranza CI, Kamar MJ, Kaudia AA, Kimiti DW, Luz AC, Matos P, Metternicht G, Neff J, Nunes A, Olaniyi AO, Pinho P, Primmer E, Quandt A, Sarkar P, Scherr SJ, Singh A, Sudoi V, von Maltitz GP, Wertz L, Zeleke G (eds) Land restoration for achieving the sustainable development goals: an international resource panel think piece. International Resource Panel. United Nations Environment Programme, Nairobi

Jardine A, Speldewinde P, Carver S, Weinstein P (2007) Dryland salinity and ecosystem distress syndrome: human health implications. EcoHealth 4:10–17

Lal R (2009) Soil degradation as a reason for inadequate human nutrition. Food Sec 1:45–57

Lal R (2015) Restoring soil quality to mitigate soil degradation. Sustainability 7:5875–5895

Lambin EF, Meyfroidt P (2011) Global land use change, economic globalization, and the looming land scarcity. Proc Natl Acad Sci 108:3465–3472

Lilley B (1997) An increase in hookworm infection temporally associated with ecologic change. Emerg Infect Dis 3:391–393

McMichael AJ, Powles JW, Butler CD, Uauy R (2007) Food, livestock production, energy, climate change and health. Resource document. https://www.lexisnexis.com

Meers E, Van Slycken S, Adriaensen K, Ruttens A, Vangronsveld J, Du Laing G, Witters N, Thewys T, Tack FMG (2010) The use of bio-energy crops (*Zea mays*) for 'phytoattenuation' of heavy metals on moderately contaminated soils: a field experiment. Chemosphere 78:35–41

Norris CE, Quideau SA, Bhatti JS, Wasylishen RE, MacKenzie MD (2009) Influence of fire and harvest on soil organic carbon in jack pine sites. Can J For Res 39:642–654

Parrotta JA, de Pryck JD, Obiri BD, Padoch C, Powell B, Sandbrook C, Agarwal B, Icko-witz A, Jeary K, Serban A, Sunderland TCH, Tran NT (2015) The historical, environmental and socio-economic context of forests and tree-based systems for food security and nutrition. In: Vira S, Wildburger B, Mansourian C (eds) Forests and food: addressing hunger and nutrition across sustainable landscapes. Open Book Publishers, Cambridge, pp 73–136

Pimentel D, Cooperstein S, Randell H, Filiberto D, Sorrentino S, Kaye B, Nicklin C, Yagi J, Brian J, O'Hern J, Habas A, Weinstein C (2007) Ecology of increasing diseases: population growth and environmental degradation. Hum Ecol 35:653–668

Qi J, Yang L, Wang W (2007) Environmental degradation and health risks in Beijing, China. Arch Environ Occup Health 62:33–37

Rakshit A, Abhilash PC, Harikesh A, Singh B, Ghosh S (2017) Adaptive soil management: from theory to practices. Springer, Singapore, 572 p

Sarkar D, Kar SK, Chattopadhyay A, Rakshit A, Tripathi VK, Dubey PK, Abhilash PC (2020) Low input sustainable agriculture: a viable climate-smart option for boosting food production in a warming world. Ecol Indic 115:106412

Sazawal S, Black RE, Menon VP, Dinghra P, Caulfield LE, Dhingra U, Bagati A (2001) Zinc supplementation in infants born small for gestational age reduces mortality: a prospective, randomized, controlled trial. Pediatrics 108:1280–1286

Sharma SB (2017) The relevance of traditional ecological knowledge (TEK) in agricultural sustainability of the semi-arid tropics. In: Adaptive soil management: from theory to practices. Springer, Singapore, pp 453–463

Sharma SB, Trivedi MH, Sayeed RZ, Thivakaran GA (2014) Study on the status of soil phosphorus in context with phosphate solubilizing microorganisms in different agricultural amendments in Kachchh, Gujarat, Western India. Ann Res Rev Biol 4:2901–2909

Stasinos S, Zabetakis I (2013) The uptake of nickel and chromium from irrigation water by potatoes, carrots and onions. Ecotoxicol Environ Saf 91:122–128

Tripathi V, Dubey RK, Edrisi SA, Narain K, Singh HB, Singh N, Abhilash PC (2014) Towards the ecological profiling of a pesticide contaminated soil site for remediation and management. Ecol Eng 71:318–325

Tripathi V, Edrisi SA, Chen B, Gupta VK, Vilu R, Gathergood N, Abhilash PC (2017) Biotechnological advances for restoring degraded land for sustainable development. Trend Biotechnol 35:847–859

Wall DH, Six J (2015) Give soils their due. Science 347:695–695

Wani SP, Chander G, Anantha KH (2017) Enhancing resource use efficiency through soil management for improving livelihoods. In: Adaptive soil management: from theory to practices. Springer, Singapore, pp 413–451

Warren GP, Alloway BJ, Lepp NW, Singh B, Bochereau FJM, Penny C (2003) Field trials to assess the uptake of arsenic by vegetables from contaminated soils and soil remediation with iron oxides. Sci Total Environ 311:19–33

Yang XE, Chen WR, Feng Y (2007) Improving human micronutrient nutrition through biofortification in the soil–plant system: China as a case study. Environ Geochem Health 29:413–428

Yu L, Zhu J, Huang Q, Su D, Jiang R, Li H (2014) Application of a rotation system to oilseed rape and rice fields in Cd-contaminated agricultural land to ensure food safety. Ecotoxicol Environ Saf 108:287–293

Zhang Y, Biswas A (2017) The effects of forest fire on soil organic matter and nutrients in boreal forests of North America: a review. In: Adaptive soil management: from theory to practices. Springer, Singapore, pp 465–476